METHOD AND SYSTEM OF DETERMINING USER TERMINAL POSITION USING A MEASURED SIGNAL PROPAGATION DELAY AND DOPPLER SHIFT OF A COMMUNICATIONS LINK

RELATED APPLICATIONS

This application is based on and claims benefit from provisional application entitled "Efficient Method to Determine the Position of a User Terminal Using Measured Delay and Doppler of the Communications Link" which was filed on May 7, 1998, and respectively accorded Ser. No. 60/084,634.

TECHNICAL FIELD OF THE INVENTION

The present invention relates generally to position determination, and in particular, to a method and system of determining the location of a user terminal on the surface of the earth using signal propagation delay and Doppler shift derived from a communications link between the user terminal and a mobile radio frequency (RF) source, such as a satellite.

BACKGROUND OF THE INVENTION

In mobile communications systems, user terminal (UT) position determination based on signal propagation delay and Doppler shift is known. Typically, the propagation delay and Doppler shift are derived from a radio-frequency (RF) carrier transmitted between the UT and a moving transceiver, for example, a transceiver included on a moving airplane or satellite. The Doppler shift is a well known physical phenomenon and represents the observed change in frequency of the propagated RF wave that occurs due to the relative motion between the UT and the transceiver. The measured signal propagation delay is the amount of time required for an electromagnetic signal to travel between the UT and the moving transceiver. From this delay, it is easy to calculate the distance separating the UT and transceiver by multiplying the delay by the speed at which the electromagnetic signal travels, which is generally at or near the speed of light.

One approach to determining UT position is to represent the signal propagation delay and Doppler shift as a system of equations that are functions of the UT position. For example, the propagation delay can be a function f of the UT position, while the Doppler shift can be a function g of the same.

$$\text{propagation delay} = f\,(\text{UT position})$$

$$\text{Doppler shift} = g\,(\text{UT position})$$

To determine the UT location using this approach, the system of equations is solved for the UT position. This is usually an iterative procedure, such as the Newton-Raphson Method, that numerically searches for an approximation of the UT position. Such an approach is computationally intensive, requiring substantial computer resources, such as processor bandwidth, memory, and the like. Consequently, this approach is impracticable in systems where computational resources and response times are limited, such as mobile communication systems. For instance, in satellite mobile communication systems, it may be necessary to perform 100–200 UT position determinations per second during peak usage. Another drawback to this approach is that its search uses two pieces of information, namely, the delay and Doppler, which yields two possible UT positions, and thus two possible solutions to the system of equations. Such situations are generally fatal to numerical search techniques, as they often cannot converge or converge to the wrong solution.

Another conventional approach to determining the UT position is to rely on the Global Position System (GPS). However, GPS receivers are expensive. Requiring each UT in a communication system to include a GPS receiver would dramatically increase costs. In addition, on cold-start power up, it often takes a GPS receiver several minutes to acquire its position. This lengthy acquisition time is impracticable in many applications. Moreover, in such a system, each UT position determination may need to be performed at the beginning of a phone call without noticeable delay to the user.

SUMMARY OF THE INVENTION

It is an advantage of the present invention to provide a novel method and system for determining UT position as a function of measured signal delay and Doppler shift. The method and system disclosed herein is significantly faster and less expensive, i.e., requires less computer resources, than conventional positioning techniques, such as GPS.

According to one embodiment of the invention, a system for determining the location of the UT on the surface of the earth includes a receiver and a processor. A ground station tracks an orbiting satellite, providing satellite position and velocity information to the processor. The receiver can measure a signal propagation delay and Doppler shift of an electromagnetic signal transmitted between the UT and the satellite.

The propagation delay and Doppler shift are provided to the professor along with the satellite velocity and position. The processor then determines the location of the UT by iteratively applying both a spherical and a refined approximation of the earth's shape. Initially, the UT's position is estimated using a spherical approximation of the earth. A set of closed-formed equations can be evaluated directly to yield this estimation. Next, the earth's radius at the estimated location is adjusted according to the refined model of the earth, such as the WGS-84 ellipsoid model of the earth. The UT location is then re-estimated using the spherical approximation and updated radius. The approximations are repeated until the estimated UT location converges to a predetermined level of accuracy. Using this approach, convergence to a position solution is assured.

It will be understood that both the foregoing general description and the following detailed description are exemplary and intended to provide further explanation of the invention as claimed. The accompanying drawings provide an understanding of the invention as described in the embodiments to illustrate the invention and serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram of a mobile communications system in accordance with an embodiment of the present invention;

FIG. **2** is a perspective view of a satellite orbiting the earth and a UT located on the surface of the earth;

FIG. **3** is a block diagram of a position determination unit (PDU) included in the communications system of FIG. **1**;

FIG. **4** is a flowchart diagram illustrating a method of determining the user terminal location in accordance with an embodiment of the present invention;